International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 8, Issue 4, Aug 2018, 575-584

Original Article

PREPARATION AND MECHANICAL CHARACTERIZATION OF AL7075-SILICON NITRIDE MMC'S

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ABSTRACT

The present works describes the mechanical properties of Al 7075 metal matrix composites reinforced with Si3N4. Si3N4 particles of size 325 mesh were taken as the reinforcement material to prepare the metal matrix composites by using stir casting technique. The percentage of reinforcement varied from 0 to 12% wt in steps of 3%. Mechanical characterization such as tensile strength hardness test, density tests were conducted as per ASTM standards. Experiment results reveal that there is an improvement in Ultimate tensile strength and hardness properties with the increase in the weight percentage of reinforcement. Optical microscopy technique was used to examine microstructures of the sample specimens and the microstructure revealed uniform distribution, of particles and presence of reinforcements in the matrix phase. A fractured surface on the tensile test specimen was investigated to determine the fracture mechanism by using scanning electron microscope. Experimental studies invoke that the 12%wt of Si3N4 increases the tensile strength by 7% and hardness values by 8% compared with that of as cast Al7075. Results also evident that there was a decrease in ductility and percentage of elongation with the increase in the percentage reinforcement.

***KEYWORDS*: Al 7075, Tensile Strength, Hardness Test, Density Tests & Silicon Nitride**

Received: May 19, 2018; **Accepted:** Jun 09, 2018; **Published:** Jul 17, 2018; **Paper Id.:** IJMPERDAUG201859

INTRODUCTION

Bauxite ore is a chief source of aluminum alloy. Aluminum 7075 is a lightweight material hence used for automotive applications and aircraft material. Main alloying element of Al7075 is Zinc and its main advantageous engineering properties are the high strength to weight ratio, moderate machine ability, and resistance to fatigue. Boron carbide is a ceramic material of typically brittle in nature and its crystal structure is of complex nature of icosahedron-based borides. Main properties of Boron carbides are Low thermal conductivity, Susceptible to thermal shock failure, outstanding hardness, extremely brittle, Semiconductor, Good thermal-neutron capture. In the present investigation, Al7075 is used as matrix phase and Silicon Nitride is used as a reinforcement material for the strengthening of the MMC's.

Al 7075 Alloy reinforced with Magnesium oxide nano powder, processed by stir casting has been studied. Al 7075 matrix with 10% of magnesium oxide powder particulates shows higher micro-hardness. Further, it shows more resistance to wear with the increase in magnesium oxide particles. However, with the increase of magnesium oxide beyond 10% does not show any considerable improvement in resistance to wear. Experimental results show that by increasing percentage of reinforcement it founds that increasing wear rate and wear volume.

Aluminum alloy 7075 reinforced with magnesium oxide produced by two-step stir casting method with different weight %[1].

Everton Rodrigues de Araujo et.al fabricated Aluminum 6061 MMC's by using silicon nitride as reinforcement, results shows the decrease in wear rate with the higher hardness number. Results indicated that tensile properties increased with increase in % of Si_3N_4. Optical microscopy study reveals that uniform dispersion of reinforcement [2].

Mohan et.al investigated the Mechanical and tribological properties of hybrid composites, were AA430 was used as a matrix material, SiC and MgO were.used as reinforcement material using the Liquid metallurgical technique. Experimental results showed that increasing the percentage of reinforcement increases the tensile strength and also the hardness. It further showed increasing the percentage of SiC+MgO, the coefficient of friction is decreased. Al6061 alloy reinforced with the TiC is fabricated by using stir casting technique[3]. Aluminum alloy reinforced with ceramic particle like TiC is significantly used in automobile, aircraft, marine, sports and recreation application.

Mohan Kumar and Govindaraju investigated on the fracture behavior of Aluminum 7075 alloy with an Electroless Nickel coating with different thickness. SEM revealed that the adhesion between the 7075 alloy and Nickel coating was strong and the coating was uniform. Fracture toughness of the coated specimen increased significantly with coating thickness[4]. Aluminum 7075 alloys with the different thickness of zinc/cadmium coating also increases Fracture toughness value in compared to that of uncoated aluminum 7075-T6 alloy [5].

Pramod R and Shashi Kumar M. E. evaluated the mechanical and insulation properties of Nomex-T410 and HS glass polymer matrix composites. This had enhanced the mechanical properties and at the same time contributing to the superior electrical insulation properties through the dielectric test when compared to the existing insulators. The PMC also proved its chemical inertness and sustained higher temperatures [7].

J. B. Fogagnolo et.al investigated the mechanical properties of A6061-Si_3N_4, ZrB_2 MMC with varying percentage of reinforcement. According to the ASTM standards tensile, hardness properties were evaluated. AA6061- Si_3N_4 reinforced MMC exhibited. very good mechanical properties under the T6 heat treatment condition compared to the as-cast MMC of Al6061 alloy and also the dry sliding behavior of AA6061- Si_3N_4 under T6 exhibits a very good wear resistance with the increased wt. % of reinforcement [6].

METHODOLOGY

Liquid Metallurgy Technique

Aluminum 7075 alloy series were used as the base alloy and Silicon Nitride as the reinforcement material. The reinforcement particle size used was 325 µm and was preheated to 500°C. To increase the wettability of molten metal magnesium chips were added, as the molten metal starts to solidify at a faster rate. Adding more than 5% would lead to the porosity of the base metal. Molten Aluminum was stirred with reinforcements at a constant speed of 350 rpm for 10 min so that it creates a vortex and enhances the uniform distribution throughout the matrix phase which is necessary for adjoining the reinforcements with the matrix material. Figure 1 shows the molten metal in the furnace crucible and Figure 2. Show the stirring of Al 7075 with Silicon Nitride reinforcement. Figure 3 shows the pouring of molten metal in to die. Figure 4 showed the casted specimens.

Figure 1: Molten Metal in the Furnace Crucible

Figure 2: Stirring of AA2024 with B4C Reinforcement

Figure 3: Pouring of Molten Metal

Figure 4: Casted Specimens

Density Test

Density is a most predominant factor considered in various applications. To calculate the density of specimens, the mass of the specimen is observed using electronic digital weight scale. The volume is calculated depending on the diameter and height which is measured with the help of Vernier caliper. The specimens prepared for the density test is shown in. Figure 5. Below

Figure 5: Density Test Specimens

Hardness Test

ASTM E18 standard testing method was employed to know the hardness number of the specimen by using Rockwell hardness tester “B” scale. The type of indenter used was hardened steel ball having a dia of 1/16th of inch and the total load applied is 1000 N. The time of application of load is 15sec.

Tensile Test

The Figure 6 gives the dimensions of the tensile test specimens which is in accordance with ASTM E-8M. The test has been done in displacement control mode with a rate of 0.1 mm/min. The load and displacement were measured.

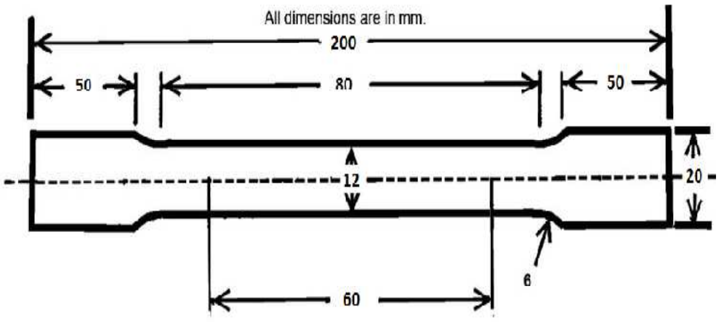

Figure 6: Tensile Test Specimen

RESULTS AND DISCUSSIONS

Density Test and Hardness Test

The density test conducted on the specimens and it revealed that the density of the samples increases as expected on the addition of the reinforcement. The Figure 7 shows that the maximum density was observed for 12% Silicon Nitride reinforcement and also graph reveals that there is no much difference in actual density values to theoretical density values. The hardness of the material improved on the addition of Silicon Nitride. The hardness value improved to a greater extent on the addition of 12% Silicon Nitride with a maximum hardness of 72 HRB. The slope of the curve shows further increase in the Silicon Nitride might improve the hardness but not appreciably.

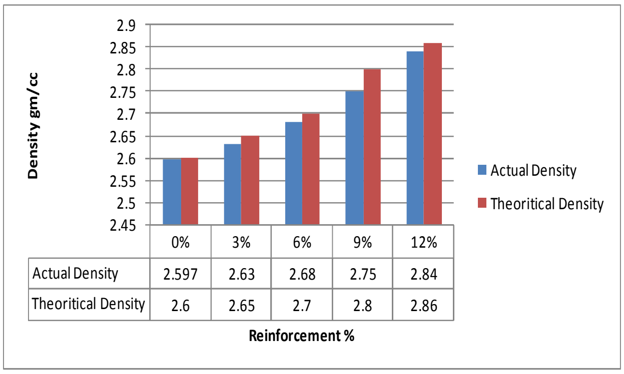

Figure 7: Variation of Density for Different Percentages of Si3N4

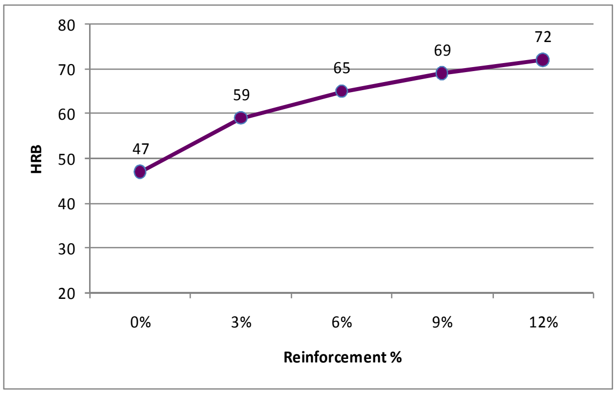

Figure 8: Variation of Hardness for Different Percentages of Si3N4

Tensile Test

The tensile test specimens after fracture are shown in the Figures revealed that the tensile strength increases with increase in weight % of Silicon Nitride. It is also observed that Silicon Nitride improved the yield strength of the material better than base Al 7075 alloy. Interfacial bonds of the material are affected because of the maximum stress experienced by the specimen. The ductility of the material decreases on the addition of the reinforcement materials. A greater reduction in ductility was observed on the addition of 12% Silicon Nitride. Percentage of elongation decreases in increasing the % of reinforcement.

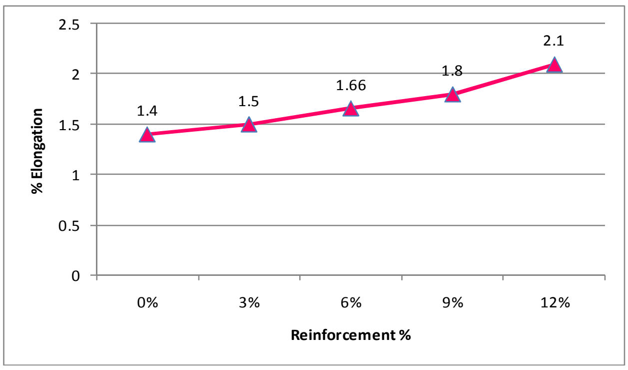

Figure 9: Percentage Elongation for Different Percentages of Si3N4

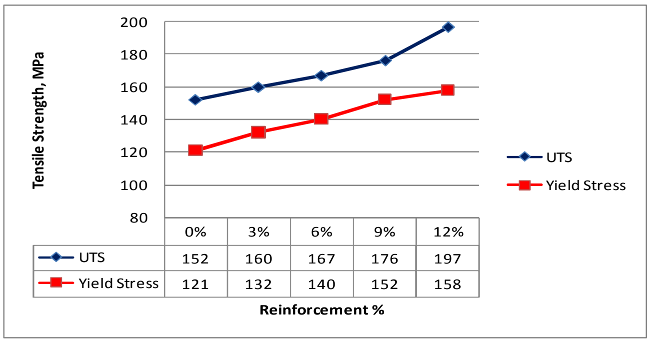

Figure 10: Strength variations for Different Percentages of Si_3N_4

Microstructure

The microstructure of Al 7075 is shown in. Figure 11. The microstructure consists of intermetallic precipitates in a matrix of Dendritic Aluminum solid solution. No segregation or porosity was seen in the section.

The microstructure of Al7075 with 3%, 6% and 9% Silicon Nitride is shown in Figure.12. This also showed the uniform distribution of the Si_3N_4 particles, because of the proper stirring action takes place during the casting process and also it observed from optical microscopy that grain refinement is increased by increasing the wt. % of Si_3N_4 particles.

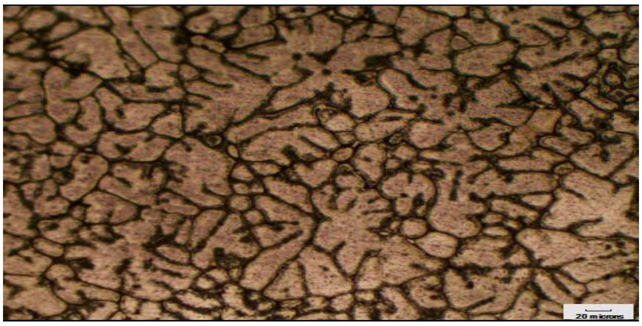

Figure 11: Microstructure of Al 7075

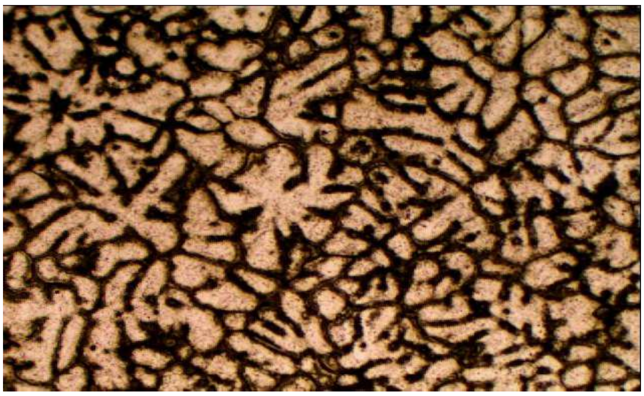

Figure 12(a):.Microstructure of Al 7075 with 3% Si3N4

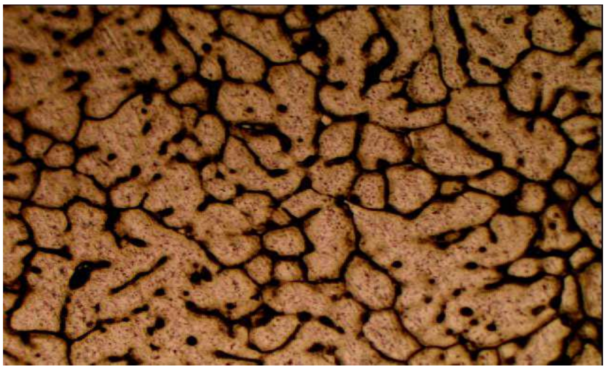

Figure 12(b): Microstructure of Al 7075 with 6% Si3N4

Figure 12(c): Microstructure of Al 7075 with 9% Si_3N

SCANNING ELECTRON MICROSTRUCTURE ANALYSIS

Fractured surface of the tensile specimens are subjected to a fractography test. Typical fractographs of Al 7075 tensile test specimen Figure 13 (a) shows an. uneven distribution of the large dimples. Experimental studies reveal that the reinforcement particles are rarely fractured. In Figure 13 (C) fractured specimens can be seen reinforcements are breaks up longitudinal and transverse directions. Breaking up of the reinforcements is indicating the increased stress on the specimen. Strain induces on the reinforcements increases as the increase on the loads. Reinforcements pull-out observed in the matrix composite indicating that strong adhesion between the matrix and reinforcement phase in Figure 13(B). There is no gap between the interfacial region on the matrix and reinforcement. Mixed mode failure both ductile and brittle fractures are observed and tear fracture, dimples are seen during SEM analysis

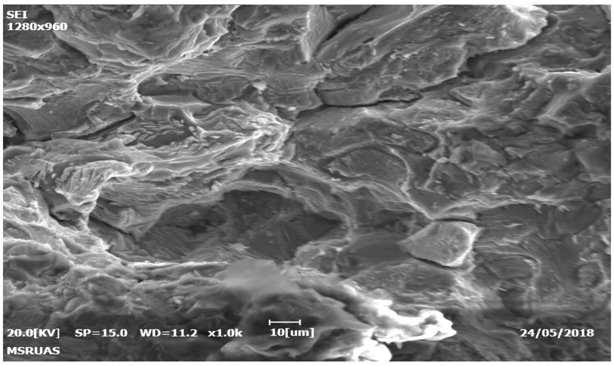

Figure 13(a): Fractographs of the Tensile Specimen Unreinforced Shows Uneven Distribution of the Large Dimples

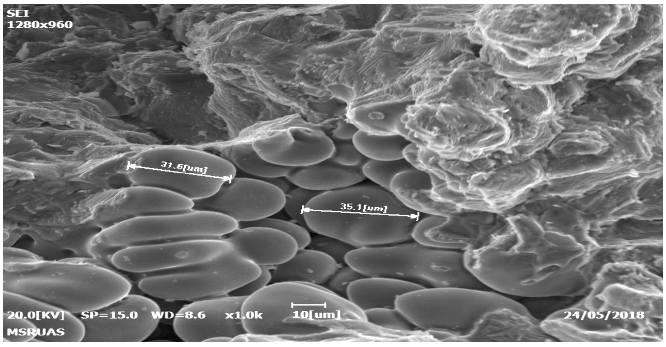

Figure 13 (b): Fractrographs of the Tensile Specimen Shows Non-Fractured Reinforcement from the Specimen

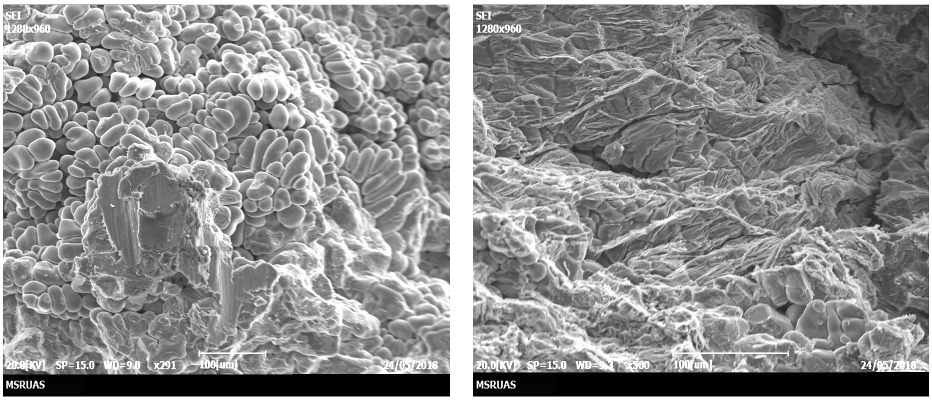

Figure 13 (c): Fractrographs of the Tensile Specimen Shows Fractured and Pullout Reinforcement from the Specimen

CONCLUSIONS

The density of the material was observed to increase with the addition of reinforcement materials to the matrix material. Aluminum 2024 reinforced with Boron Carbide is effective in increasing the tensile strength of the composite material. The optimum tensile strength was observed in the sample containing 6% Boron Carbide by weight. Addition of the reinforcement materials results in a reduction in the ductility of the material. It is also observed that Young's modulus of the MMC is increased with the effect of B4C reinforcement in Matrix phase. From the microstructure, it can be seen that the intermetallic precipitates are present and they are uniformly distributed across the matrix material.

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